Nature and Properties of Waves

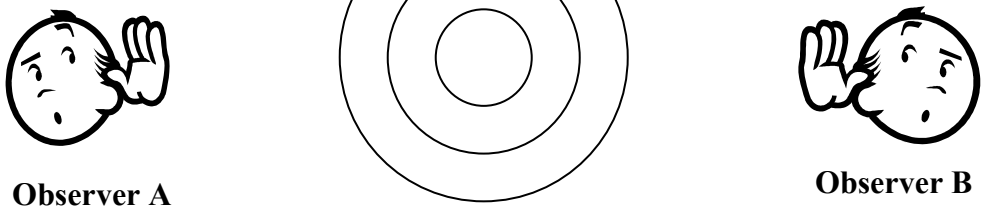
PS-7 The student will demonstrate an understanding of the nature and properties of mechanical and electromagnetic waves.

PS-7.7 Explain the Doppler effect conceptually in terms of the frequency of the waves and the pitch of the sound.
Taxonomy Level: 2.7-B Understand Conceptual Knowledge

Key Concepts:
Doppler Effect
Frequency, Wavelength, Pitch

Previous/Future knowledge: In the 8th grade students explained hearing in terms of the relationship between sound waves and the ear (8-6.5). In Physical Science the students will expand their concept of wave frequency and how they hear frequency of sound as pitch by explaining the Doppler effect.

It is essential for students to
- Understand that the *Doppler effect* is an apparent frequency shift due to the relative motion of an observer and a wave source.
- Understand the relative motion of a wave source and an observer.
  - A Doppler shift occurs when a wave source is moving toward an observer or away from the observer**.**
  - A Doppler shift also occurs when the observer is moving toward or away from the wave source.
  - There is no shift when the source and observer are not moving toward or away from each other.



Observer A **Observer B**

Waves from a source that is not moving.

The example above shows a wave source and observers that are not moving relative to one another. If the wave source in the example is a sound wave, observer A and observer B would hear the same pitch (frequency) that the source is producing.

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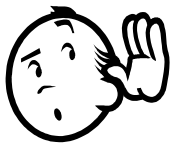
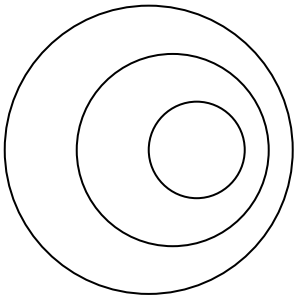


Observer A



Waves from a source that is moving to the right.

Observer B

The example above shows a wave source that is moving toward observer B. If the wave source in the example is a sound wave then observer B will hear a higher pitch (frequency) and observer A will hear a lower pitch (frequency) than the source is actually producing.

Situation – wave source moving toward or away from an observer:

- As a wave source approaches an observer, the observer perceives a higher frequency than the source is producing. Wavelengths are shorter and the frequency is higher in front of a moving source.
  - The source of the wave is catching up with the wave in front of it. When it produces the next pulse the resulting wavelength is shorter. A shorter wavelength means that there will be a higher frequency
  - If the wave is a sound wave, the observer will perceive a pitch that is higher than the pitch produced by the source.
- When the wave source is moving away from the observer, he/she will perceive a lower frequency than the source in producing. Wavelengths are longer and the frequency is lower behind a moving source.
  - The source of the sound is moving away from the wave behind it. When it produces the next pulse the resulting wavelength is longer. A longer wavelength means that there will be a lower frequency.
  - If the wave is a sound wave, the observer will perceive a lower pitch that the source is producing

Situation – the observer moving toward or away from the wave source:

- When the observer is moving toward a wave source, he/she would perceive a higher frequency than the source is producing. The observer encounters waves more often than the source is producing them.
  - If the observer encounters more waves, he/she perceives a higher frequency.
  - The observer would perceive a higher pitch in the case of sound waves.
- When the observer is moving away from a wave source he/she would perceive a lower frequency than the source is producing. The waves would have to catch up with him and he/she would encounter fewer waves.
  - If the observer encounters fewer waves he/she perceives a lower frequency.
  - The observer would perceive a lower pitch in the case of sound waves.

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Misconception: Students sometimes say that the Doppler effect is observed when a source of sound and an observer move toward each other the sound gets louder and as they move away from each other the sound gets softer. While the observer will hear a louder and softer sound in these situations, this is not the Doppler effect.

It not essential for students to understand why a red shift or blue shift occurs in light.

Assessment Guidelines:
The objective of this indicator is to *explain* the Doppler effect in terms of frequency and pitch, therefore the primary focus of assessment should be to construct cause and effect models that show the effect each variable has on the perceived frequency of waves and on the pitch of sound. Assessments should be based on the fact that the relative motion between a source of waves and an observer will affect the frequency at which waves are encountered. An observer will perceive a different frequency (pitch with sound) than the frequency of the source.

In addition to *explain*, assessments may require that students

- *Identify* the frequency that the listener observes in different situations relative to the frequency that the source is producing or the pitch heard by different observers in different locations with respect to the wave source;
- *Summarize* how different situations affect the perception of relative pitch (frequency);
- *Infer* from situations the relative pitch that the listener will observe;
- *Exemplify* situations which will produce the Doppler effect with sound waves.